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To Accompany Preliminary Geologic Map of the
Hommel Quadrangle of the Moon

Introduction

The Hommel quadrangle is in the southeast highlands of the earthside hemisphere of the Moon. The major geologic units are structured terrae materials, plains-forming materials, and crater materials. Mare material is absent. In the absence of extensive stratigraphic datum horizons, the geologic units were tentatively correlated with the type areas of the lunar geologic systems (Shoemaker and Hackman, 1962; Wilhelms, 1966) by means of a graded sequence of crater morphologies.

Crater Units

The graded sequence of crater morphologies comprises five categories. Materials of rayed craters (Cc), identified by rays and by high albedo of rim material, are assigned to the youngest system, the Copernican. Materials of the four other morphologic categories are tentatively assigned ages according to apparent freshness: youngest for the freshest materials. The sequence, from most subdued to freshest and therefore presumably from oldest to youngest, is: pIc_1, pIc_2, Ic, and CEc. These categories are based on standard crater types established by Pohn and Offield (1968) through a systematic examination of crater morphology related to both age and crater size. (Eratosthenian craters and Copernican craters older than Tycho are undistinguishable in this quadrangle because morphologic criteria are not precise and rays diagnostic of Copernican craters may be covered by Tycho rays.)

Plains-Material Units

Four plains-material units (Ipc_1, Ipc_2, Ipc_3, EIps) have been mapped. They are characterized by level surfaces broken by younger craters and scattered remnants of subjacent topography. Plains units are most widespread in the northwest part of the quadrangle. There is a general structural or topographic control; plains occupy the lowest topographic regions within the map area. The four units are interpreted as volcanic; they differ mainly in density of superposed craters. This difference may result from age differences, although the significance of crater frequencies is not well established. Assuming that the frequency of craters indicates relative age for similar surfaces, unit EIps is younger than unit Ipc_3 since unit EIps has fewer total craters per unit area (fig. 1).

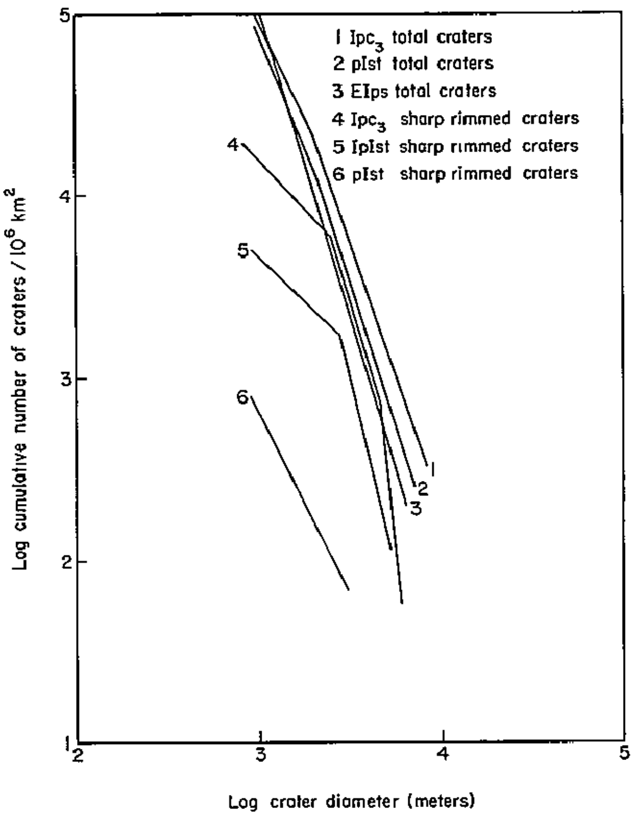

Figure 1.--Cumulative crater frequency distribution.

Smooth plains material (EIps), the most widespread of the four, occupies the floors of nearly all pre-Imbrian and Imbrian craters. This plains unit commonly occupies small depressions in units Ipc3, IpIst, and pIst. The intermediate cratered plains units (Ipc2, Ipc3) occupy much of the area between the craters Jacobi, Cuvier, and Baco. They partly bury pre-Imbrian craters and are overlain by Imbrian and younger craters. Near the eastern margin of the quadrangle there is a transition from partly flooded terra (IpIst) on the east of the cratered plains units (Ipc1, Ipc2, and Ipc3) to the structured terra (pIst) to the west.

Structured Terrae

Two units of hilly terrae (pIst, IpIst), level on a scale of tens of kilometers but displaying linear ridges and grooves or a cross-hatched structure at the kilometer scale, form most of the quadrangle surface not covered by plains or crater materials. The typical structured terrae unit (pIst) is best exposed east of the crater Pitiscus. It has prominent sets of parallel linear ridges, one trending northwest and a second slightly east to north. The terrain is covered with the faint outlines of highly subdued or buried craters. This unit is interpreted to be complexly cratered highland material. The linear features are interpreted as having been produced by movement along faults apparently related to a Moon-wide fracture system. Unit IpIst is a composite unit having all the characteristics of unit pIst but with more local flooding by units EIps and Ipcl. Unit IpIst has numerous linear ridges and domes, especially near the center of the quadrangle. These ridges and domes are interpreted as volcanic features. The distinction, then, between pIst and IpIst is that tectonic and volcanic activity occurred in the area occupied by unit IpIst during Imbrian time; whereas the area occupied by unit pIst has been dormant since the formation of the lineaments of pre-Imbrian time.

Volcanic Features

There are only a few areas of the Moon, chiefly in the maria, where evidence for the existence of volcanic features is convincing. Some features in the Hommel quadrangle resemble features in those areas and thus may be of volcanic origin. Certain domical hills and linear ridges in the quadrangle are approximate equivalents of features displayed more clearly in the region of the Marius Hills (Karlstrom and others, 1968, pl. 1-3). Linear forms are more common in the Hommel quadrangle than in the Marius Hills, possibly indicating that fissure eruptions were particularly common in one area and central pipe eruptions in the other.

Crater Frequencies

One of the most puzzling features in the region is that there are more <10 km craters on some of the plains units than on the older structured terrae (fig. 1, compare curves 1 and 2). An even greater contrast is in the distribution of sharp-rimmed craters, which are nearly an order of magnitude more numerous on plains than on structured terrae. Seemingly in contradiction to the crater statistics, however, the plains are interpreted to be younger than the terrae because (1) plains material is superposed on the terrae, (2) old, highly subdued craters that are common on the structured terrae are absent on the plains, and (3) the plains units lack structure and lineaments characteristic of the terrae region. This anomalous relationship between terrae and plains may be explained either by endogenous crater production on the plains or by more rapid erosion (hence, more rapid obliteration of craters) on the steep, rough terrae slopes.

Regional Structure

A simplified structural map is shown in figure 2. A dominant set of faults trending northwest and a second, less well developed set trending slightly east of north divide the region into blocks which have been relatively depressed or elevated. Low blocks have been almost completely flooded by plains material (EIps, Ipc_3, Ipc_2, Ipc_1), intermediate blocks partially flooded, and high blocks only slightly flooded or not flooded at all. All the possible faults are nearly continuous and the relative vertical movements (fig. 2) have been inferred from the relations of plains materials. One of the more striking lineaments, shown in figure 2 and on the

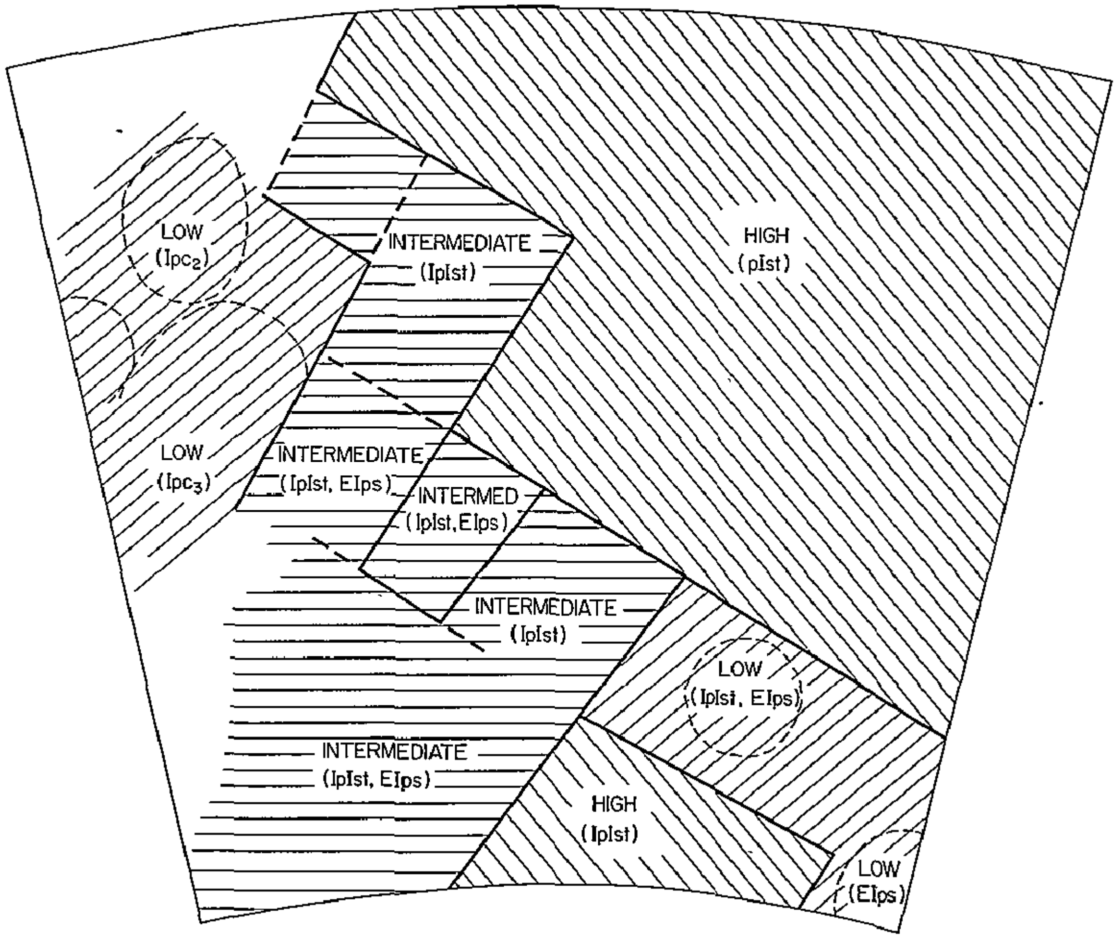

Figure 2.--Diagrammatic structural map showing relative displacement of regional blocks. Inferred faults indicated by solid lines. Dashed lines are inferred faults not represented by lineaments on the geologic map. Circular dashed lines outline inferred buried craters and show possible impact rather than tectonic origin of low blocks. Symbols in parentheses show principal surface geologic units of each block.

geologic map as a fault, trends northwest from just south of the crater Nearch for a distance of at least 200 km. Movement is interpreted as down on the southwest because that area of the structured terrae is extensively flooded. Several semicircular depressions terminate abruptly against the fault. Young craters which lie astride prominent lineaments show no evidence of being displaced, suggesting that the structural blocks formed early in lunar history and have not moved extensively since.

Summary of Geologic History

The major events of pre-Imbrian time whose record is still visible were the formation of the larger craters (Janssen in the northeast corner and Hommel) and the creation of the lunar grid. Some of the grid lineaments may have been active as faults in pre-Imbrian time, creating the large block-fault provinces which were later flooded by plains material. The Imbrian Period was characterized by episodic volcanic activity, during which the various plains-forming materials were deposited and other features interpreted as volcanic ridges and domes were formed. The highest areas were least affected by Imbrian volcanism. Volcanism continued through early Eratosthenian time and then apparently terminated. Craters formed throughout the history of the region, mainly by impact. The most recent large crater to form nearby is Tycho, 450 km northwest of the map area. Bright ray material and secondary craters which cover most of the area are evidence of that impact.

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To accompany Preliminary Geologic Map of the Schiller Quadrangle of the Moon

Geologic Setting

The Schiller quadrangle is in the southwest quadrant of the earthside hemisphere of the Moon, about 600 km south of the Mare Humorum basin. Heavily cratered terra occupies most of the quadrangle; the most prominent feature is the footprint-shaped crater Schiller. A large area of plains, here called the Schiller plains, occurs in the western part of the quadrangle, partly filling the Schiller basin, an old structure defined by two rings of mountainous terra. Regional geologic units unrelated to basins cover most of the region, but some units and structures are related to the Orientale basin, more than 1,000 km to the west-northwest.

Stratigraphy

Because the quadrangle is far from the Mare Imbrium area, where the lunar time-stratigraphic sequence was defined (Shoemaker and Hackman, 1962), it is difficult to assign ages to the major stratigraphic units. The problem was dealt with by establishing a sequence of inferred relative ages for craters on the basis of detailed morphologic comparisons (Pohn and Offield, 1968), as discussed further below, and by correlating that sequence with craters whose position (age) in the classical geologic section had already been established. The geologic units of the quadrangle could then be assigned ages by determining their superposition relations with craters.

Pre-Imbrian materials.--Blocks of mountainous terra (unit pIu) occur in two discontinuous rings which outline the Schiller basin. The extreme degradation of the basin rings and craters superposed on them indicates that the basin is the oldest structure in the quadrangle. Much of the south-central part of the quadrangle is occupied by similar degraded mountainous terrain which may consist partly of ejecta from the Schiller basin and partly of the ancient terra surface on which the basin formed, presumably by impact.

Terra-mantling materials.--Most of the terra in the quadrangle is heavily cratered and relatively flat, with a gently rolling to finely and irregularly hummocky surface in the intercrater areas. Material with this surface texture (unit Itm) partly fills valleys along the bases of mountainous terra blocks. It also appears partly or completely to cover rims of large degraded craters (pIc_3 and older) so that much of their topographic expression is so muted that a rim unit cannot be mapped. That this is an effect of mantling by a local superposed unit is indicated by the fact that craters of similar ages elsewhere on the Moon generally have

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distinct raised rims where such a hummocky surrounding unit is not present. In the Schiller quadrangle, the older the crater, the lower its rim and the more complete the apparent mantling; few pIc_2 or older craters have evident rims, and their walls also appear to be mantled, whereas only the low parts of pIc_3 crater rims appear to be covered. This material is inferred to have covered the floors of many old craters and is mapped as patches, surrounded by younger plains materials, in some craters. The mantling materials are believed to be mostly volcanic in origin, probably ash flows of variable thickness. Source vents have not been recognized but must be numerous to account for the great lateral extent of the unit in this area and elsewhere to the east in the southern highlands. Part of the unit may be colluvium of local derivation or a regolith developed essentially in place, but the general lack of topographically high source areas for a unit of such extent, and its apparent early-to-middle Imbrian age, based on crater superposition relationships, everywhere reinforce the interpretation of general volcanic origin.

Other probable volcanic mantling material occurs as small patches on the wall of the crater Longomontanus and the rims of Zuchius and Bettinus; thus, the material appears to be younger than Copernican craters and rays and is therefore the youngest material in the quadrangle.

Plains-forming materials.--Materials with smooth, nearly flat surfaces (unit Ips) partly fill most pre-Eratosthenian craters and occupy many topographic lows at various levels in the intercrater areas. On these plains surfaces, small craters (<1 km) are perhaps twice as numerous as on mare surfaces of similar age (as determined on the basis of crater-morphology distinctions described in the following section); the plains materials also have higher albedo than such mare materials. The plains embay materials ejected from the Orientale basin and form floors without visible structure in craters whose walls are broken by structure related to the formation of the Orientale basin. By tentative correlation of crater sequence and time-stratigraphic units, this indicates a lower limit of late Imbrian time for the formation of the plains. An upper limit of earliest Eratosthenian time is suggested by the fact that no crater mapped as Eratosthenian is filled by plains materials. Elsewhere, similar plains materials have been considered (Howard and Masursky, 1968; Wilhelms, 1968) as ponded volcanic terra-mantling materials (similar to the unit here called unit Itm), thick enough to cover underlying topography and form smooth surfaces. In the Schiller quadrangle and elsewhere in the southern highlands, however, a small difference seems indicated between ages of the plains materials (unit Ips) and Itm (or its equivalent in other areas). Some craters apparently are superposed on unit Itm, yet are filled by plains materials; moreover, unit Itm is structured and the plains are not (although Itm may be thin enough to show underlying structure). Also, contact relations suggest sharp truncation and embayment of unit Itm by the plains materials. Therefore unit Ips does not seem to be a ponded facies of unit Itm. On the other hand, if unit Ips is a separate localized volcanic deposit, the occurrence of so many individual source vents for plains materials, located only in topographic lows, seems implausible. The problem remains unsolved.

A younger, darker plains unit (diagonal line pattern on map) covers most of the Schiller plains. It is similar to mare units of the western part of the Moon in its low albedo and low density of small craters. The low albedo of the plains appears to extend across areas of gentle topography of Orientale satellitic materials and Itm in the Schiller plains, suggesting that dark material forms a thin cover in those areas. Because of this the dark material is interpreted everywhere as a thin blanket of relatively young ash-flow and ash-fall material, covering older smooth plains which fill most of the Schiller basin, and adjacent units of low topographic expression. Ridges and one possible dark-halo crater within the dark-plains area may mark source vents for the dark material; this association of features is similar to that in many mare areas (for example, Carr, 1966).

Crater materials.--Nearly all craters in the quadrangle are circular to somewhat polygonal, and in any given size range they appear to make up a morphologic continuum, ranging from sharp-rimmed deep craters with terraced walls and outer radial rim facies to shallow craters with smooth walls and subdued, discontinuous rims. The craters in this continuum are believed to have been produced by impact. Superposition relations indicate that craters are degraded with time because the younger of two overlapping craters is always the sharper, and because increasing subdual of craters coincides with increase in abundance and size of other craters superposed on them. It is thus inferred that subdual of craters is an aging process, accomplished by meteoritic bombardment and disruption of materials by vibrations from tectonic and impact events. Criteria for determining relative ages of craters, based on inferred progressive modifications in crater form with age, have been defined in detail by Pohn and Offield (1968). The relative crater ages have been tentatively correlated with lunar time-stratigraphic systems used by the U.S. Geological Survey and the resulting system assignment is shown by a capital letter in the symbol for crater units. The systems can be further subdivided into categories that may be comparable in scope to the series of the terrestrial stratigraphic column and these subdivisions are indicated by a numerical subscript.

Of particular interest are large clusters of craters and associated ejecta, especially those at the western edge of the quadrangle (units Iso, Ifo). These clustered craters are identified as secondaries from the Orientale basin because they are part of a radial array which extends a great distance outward from the basin ejecta blanket. Also, crater-age criteria indicate that they are the same age as the basin. Craters 5 to 15 km in diameter, of Orientale age but not necessarily in linear radial groups, are unusually abundant in the quadrangle and probably are satellitic to Orientale. These clusters and single craters are the only secondary craters of a lunar basin yet identified on the Moon. The Orientale basin is inferred to be late Imbrian in age.

A possible nonimpact crater is Schiller. The elongate shape could be due to coalescence of two or three round impact craters, but this seems unlikely because doublet craters of probable impact origin generally have some vestige of a wall between them and Schiller apparently lacks such a wall. The crater is located on a basin ring structure, and the axis of Schiller is alined with a poorly developed tectonic-grid direction, which is marked by the linear ranges on its floor and the conspicuous trough extending to a smaller crater from the southeast end of the crater. As Schiller appears to extend along a fault, it may have formed as a single elongate volcano-tectonic feature or by the coalescence of two slightly elongate smaller calderas. If Schiller is a volcanic crater, determination of its age by the age criteria used for impact craters may not be valid. It is, however, older than unit Itm and still only moderately subdued in appearance; this and superposition relations with craters of probable impact origin indicate a late pre-Imbrian age. Crater Rost B and the craters on the eastern rim of Schiller also are suspect of volcanic origin because of their locations. The crater Scheiner B has unusual rim and central peak morphology and may be volcanic. Small chain craters, also probably of volcanic origin (unit Ich), occur east and west of the crater Scheiner.

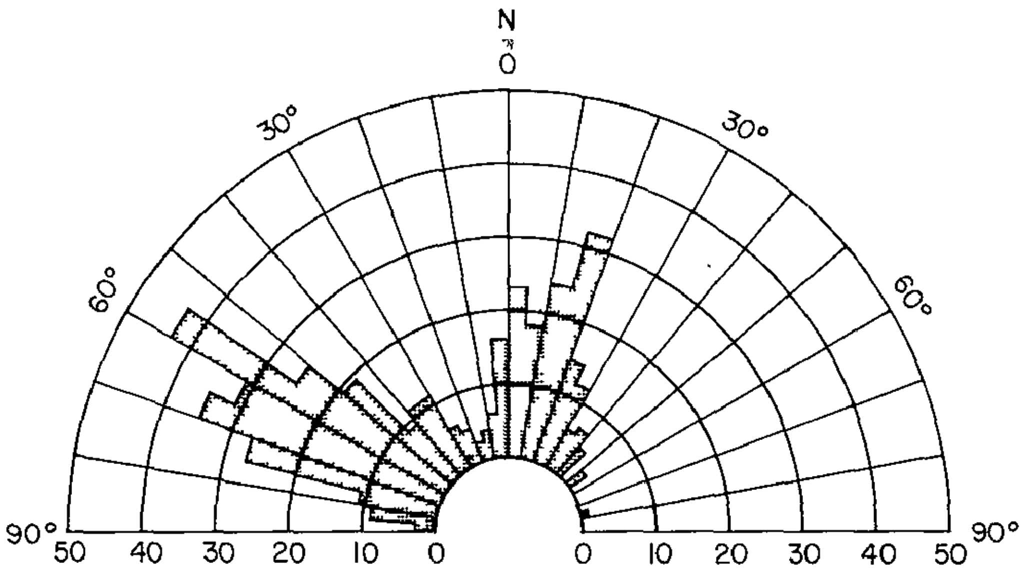
Structure

Linear west-northwest-trending valleys are prominent in the west half of the quadrangle. They are radial to the Orientale basin and are considered to have been sculptured by vertical fault movements produced by the basin-forming event. Long narrow ridges on the Schiller plains alined with this sculpture probably are volcanic vents localized by faults. A system of ridge and valley lineaments of north-northeast trend is also best developed in the west half of the quadrangle. The orientation of these lineaments suggests that they are lines of radial sculpture associated with the Humorum basin. Others are concentric to Orientale and may be related to that basin. The older, possible Humorum lineaments may have been reactivated by the Orientale event. Lineaments are much less abundant and smaller in the east half of the quadrangle. The accompanying figure shows the azimuth frequency distribution of lineaments. The two major systems are apparent.

Low hummocky ridges and intervening valleys in the large clusters of Orientale satellitic materials which occur in the Schiller plains area are also mapped as lineaments. These may be structural in origin but are more likely depositional. They probably formed by outward spray of ejecta in a herringbone pattern from a linear focus of impacting material. Similar patterns are very clear in satellitic materials around large fresh impact craters.

Geologic History

The earliest decipherable event in the area was the formation



Azimuth-frequency distribution of lineaments

of the Schiller basin. Aside from formation of major craters such as Longomontanus, Clavius, and Schiller, and possible faulting associated with the Humorum basin-forming event, no major geologic event is recorded until Imbrian time, when widespread mantling of the terra took place (unit Itm). In late Imbrian time much faulting, cratering, and deposition of ejecta occurred as a result of the event which formed the Orientale basin. This event was followed by the emplacement of smooth plains materials which fill most older craters, the Schiller basin, and many low areas in the terra. The last major event was the emplacement of dark material as a surficial covering in the Schiller plains area. Formation of the crater Zuchius in late Copernican time resulted in widespread distribution of fresh ejecta across the southwest corner of the quadrangle. Still more recently, dark material was emplaced in three small areas (unit Cdm).

Impact cratering and mass wasting have occurred throughout the history of the quadrangle, covering many surfaces with debris and exposing others. Bright surfaces are probably areas where materials have been recently exposed; they are mapped as unit Cs.

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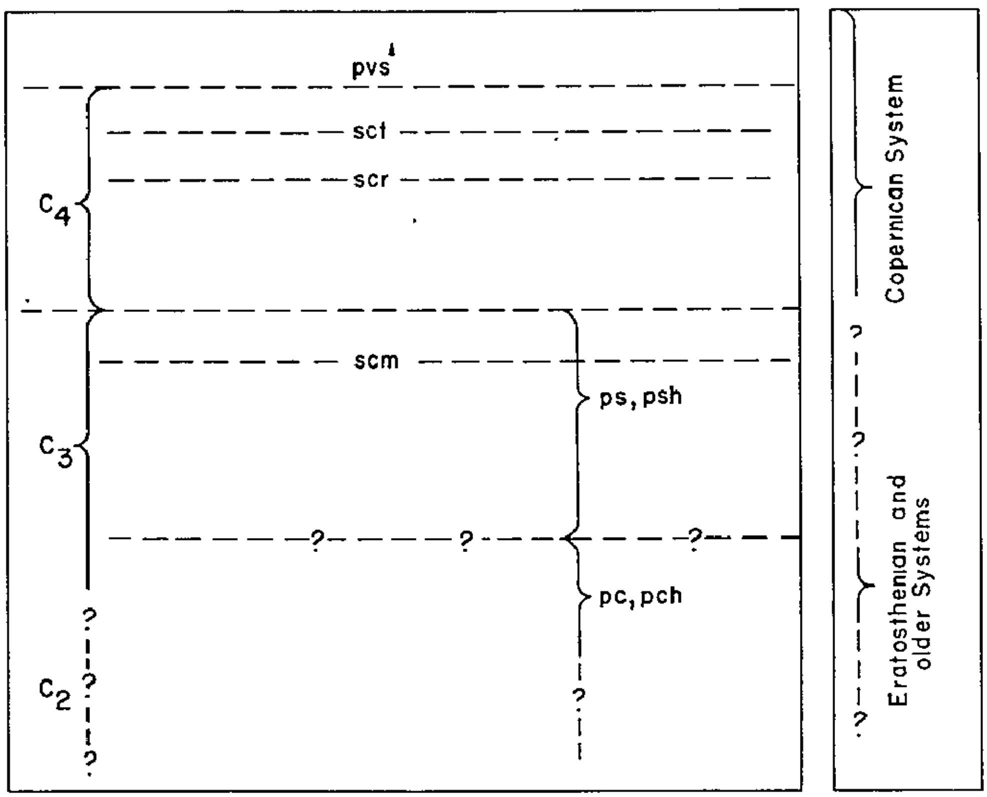
Text for Preliminary Geologic Map of the
Clavius Quadrangle of the Moon

INTRODUCTION

The type localities of most of the lunar time-stratigraphic systems and series recognized to date are in the vicinity of Mare Imbrium, 3,000 km north of the Clavius quadrangle. Mare material and other rock-stratigraphic units that define the Imbrian System in the Mare Imbrium area could not be traced into the map area; thus, correlation of Eratosthenian, Imbrian, and pre-Imbrian units was not attempted. An attempt has been made to separate the Copernican from older systems (see table below), although identification of the lower boundary of the Copernican System is also uncertain.

Generalized stratigraphic column for Clavius quadrangle



A generalized stratigraphic column for the Clavius quadrangle is presented in the table. Capital letters, used to designate age on maps of other quadrangles, have been omitted. The symbols used in the table are described in the Explanation. Dashed horizontal lines indicate excellent, albeit local, time boundaries. Queried dashed lines indicate uncertainty. The column was constructed from the following general considerations. A meteorite impact is an almost instantaneous event and, where recognized, defines a good time boundary. Satellitic crater materials around the craters Tycho, Rutherfurd, and Moretus--designated sct, scr, and scm, respectively--are believed to have formed when those craters formed by impact, and these materials divide the column. Two plains-forming units, not formed by impact and probably not by an instantaneous event, also divide the column: one is smooth (ps), the other cratered (pc). Both have an attendant hummocky facies (psh and pch). On the basis of apparent overlap relations, the smooth plains unit is believed to be younger than the cratered one. Finally, relative crater ages are assigned according to the general appearance of the craters: those that appear to be most degraded (c_1 and c_2) are believed to be the oldest. Relatively young craters, designated as c_3, have rims that vary from relatively subdued to relatively sharp. (The floors of these craters are filled by units ps and pc to various depths. The sharp-rimmed c_3 craters generally have less ps and pc materials on their floors than the subdued c_3 craters. This suggests that the plains units were not formed instantaneously; rather, they span a considerable time period.) Those craters devoid of plains-forming units are designated as c_4.

GEOLOGY

The region covered by the Clavius quadrangle is in the southern highlands, about 120 km south of Mare Nubium. The region is characterized by a densely cratered terra topography. No definitely recognizable mare is present.

Two rather indistinct general topographic and geologic provinces can be distinguished: a western province, which comprises about 97 percent of the area and an eastern province, in the area around the craters Cuvier and Heraclitus in the northeast corner of the quadrangle.

The western province is blanketed by extensive, relatively uncratered plains material (units ps and psh). Two general subprovinces can be recognized, one of which, the Clavius subprovince, is relatively smooth and the other, the Lilius subprovince, is relatively hummocky. The Clavius subprovince extends from the western part of quadrangle to a line approximately through the eastern edges of the craters Maginus, Deluc, and Deluc G. The Lilius subprovince includes the remainder of the quadrangle except for the area covered by the eastern province.

Plains materials.--In the Clavius subprovince, intercrater areas and crater floors are characteristically occupied by laterally extensive deposits of the smooth facies of the smooth plains unit (ps), although the hummocky facies (psh) also covers large areas. In a few places, the smooth facies drapes over a crater wall and fills the interior (fig. 1A). This is not common, however, possibly because material deposited on a crater wall is usually unstable and slumps downward to form a low mound on the crater floor adjacent to the wall (figs. 1C, 4B). The smooth

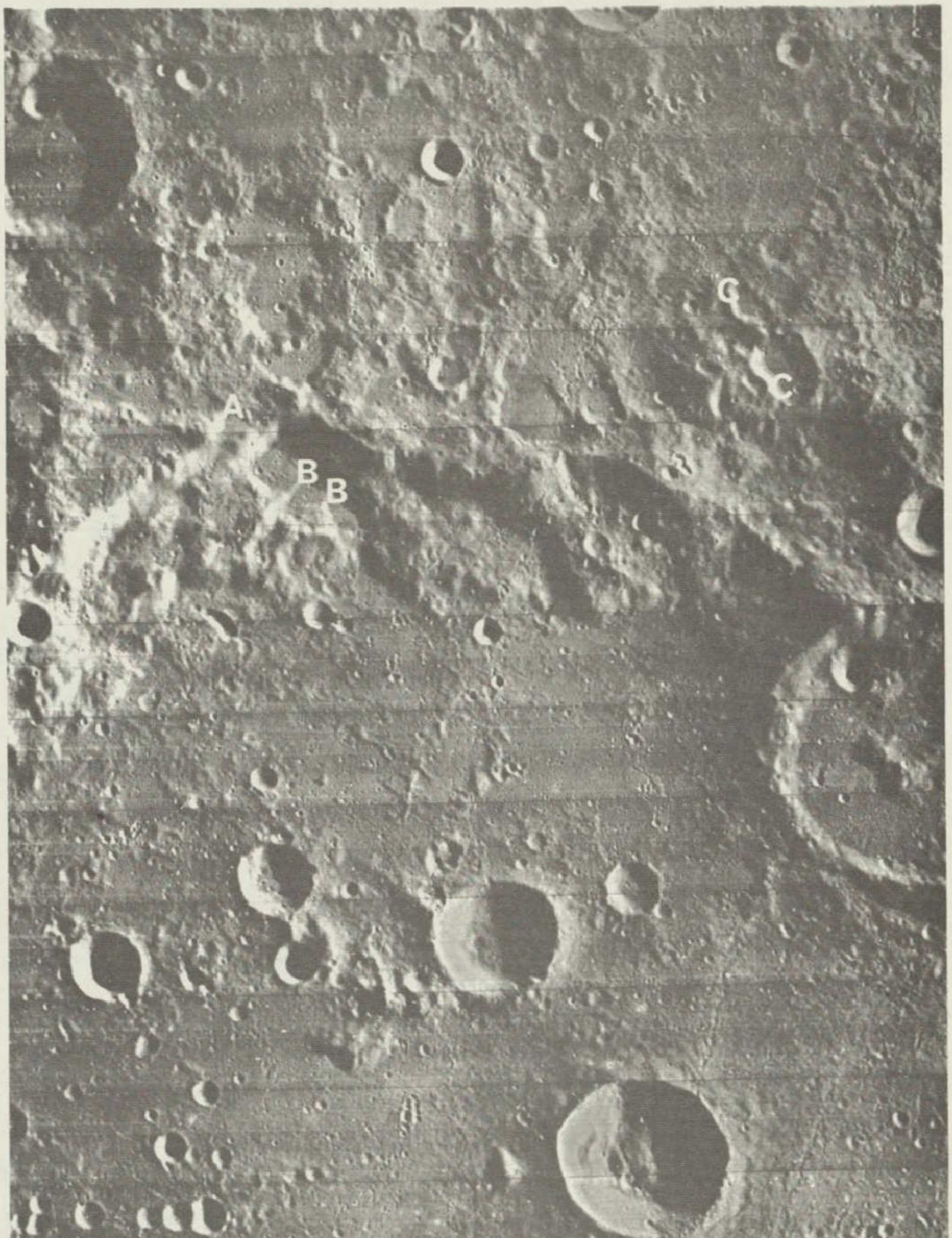


Figure 1.--Portion of northern wall of Clavius. Locally, A, the plains unit (ps) appears to drape over the crater wall; also occurs as pools of smooth material in pockets formed by fault blocks, B. Plains unit material commonly slumps into craters and forms low mounds at the foot of slopes, C.

facies also occurs in pockets formed by fault blocks (for example, on the northern side of Clavius, fig. 1B). The textural characteristics of both facies appear to be uniform, and the general appearance of the area suggests that the entire surface has been mantled by the plains-forming units, but without obscuring all pre-existing topography. In areas of low relief where the plains-forming unit completely buried low hummocks and small craters, the surface is relatively flat (unit ps). In areas of moderate or high relief, the plains unit could not completely bury the hummocks and large craters, but nevertheless mantled them.

In the Lilius subprovince, the hummocky facies (psh) dominates intercrater areas, but patches of the smooth facies also are present in intercrater areas as well as on crater floors. The walls and floors of c_3 and older craters are partly mantled by the plains unit. A general trend toward increasing roughness of terrain from west to east is more apparent in the Lilius subprovince than in the Clavius. If, as suggested above, the hummocks represent terrain partly buried by the plains-forming unit, then the more predominantly hummocky terrain to the east may have a generally thinner blanket of the plains material.

The general distribution and relatively great extent of the plains unit and the way it mantles underlying topography are suggestive of terrestrial ash-flow or ash-fall tuffs (Smith, 1960a, b; Ross and Smith, 1961); they also suggest a source to the west. The smooth plains unit (ps) in the Clavius quadrangle is about 500 km in lateral extent, measured east-west, and covers an area of about 2.5×10^5 km^2. The unit, however, may consist of several ash flows rather than a single ash flow. Some terrestrial ash-flow tuffs extend great distances from their source. For example, the Toba tuff in northern Sumatra extends over 80 miles (Smith, 1960b, p. 814). Ash flows in the western United States cover in the aggregate about 10^6 km^2 (Elston, 1965, p. 818). Ash-flow tuffs may have greater mobility under lunar conditions than under terrestrial conditions (O'Keefe and Cameron, 1962) and may cover greater distances than terrestrial ones.

Terrestrial ash flows are affected by the topography over which they move. The thickness of the ash flow controls the amount and degree of welding, and the percentage of total compaction will be greater in the thicker parts of the flow (Smith, 1960a, p. 158). This differential compaction allows the underlying topography to be manifested at the surface. Figure 2 diagrammatically shows the effect of a hypothetical buried terrain on an ash flow. In depressions (E) and other areas of low relief (A and C), the surface expression of the flow is relatively flat and the flow is relatively thick. In areas of moderate or high relief (B, D, and F), the surface expression of the flow is hummocky, reflecting the buried topography, and the flow is relatively thin. The buried terrain in figure 2 is topographically similar to areas of the Moon that have not been mantled by plains units. In the Clavius quadrangle, the plains unit has apparently

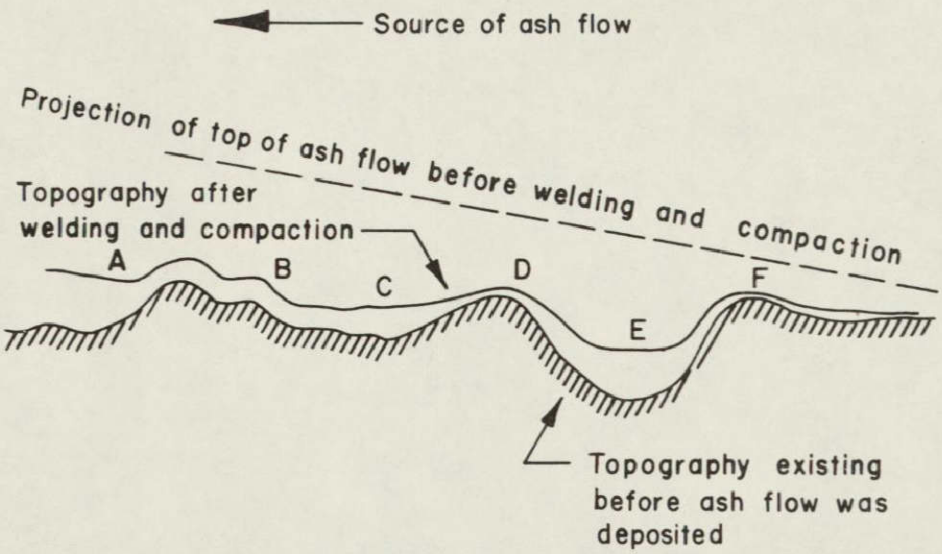


Figure 2.--Diagrammatic cross section showing effect of buried topography on thickness and distribution of ash flow. Not drawn to scale. Modified from Smith (1960a).

mantled this type of terrain in much the same way that a terrestrial ash flow would. Similar relations, however, would result from ash fall.

The eastern (Cuvier) province is characterized by a moderately cratered plains unit (pc) with numerous small (<1 km) craters. Where the unit is moderately hummocky, it is designated as pch. The relation between the smooth and hummocky facies in this province is probably similar to that in the western province--that is, the relatively smooth areas may represent relatively thick deposits of the unit, whereas the hummocky areas may represent thin deposits that only partly bury the underlying terrain. This plains unit may be an ash-flow or ash-fall sequence similar to the western plains unit. Cursory observations outside the Clavius quadrangle reveal no obvious source for the unit.

The boundary between the eastern (pc, pch) and western (pc, psh) plains-forming units is indefinite; however, the western plains unit appears to overlap the eastern plains unit in several areas, particularly on the floors of Cuvier and Heraclitus (fig. 3A). No extensive plains units older than ps and younger than c_2 craters are believed to be buried beneath the smooth plains unit in the western province because craters older than the smooth plains (c_1, c_2, and c_3) are filled to a comparable depth (for example, Deluc G and Deluc C), whereas c_1 or c_2 craters would be more deeply filled than c_3 craters if there had been a plains unit deposited between c_2 and c_3 time. The older cratered plains unit to the northeast (pc) therefore probably does not extend very far under the smooth unit. The cratered plains unit may not even extend to the crater Lilius.

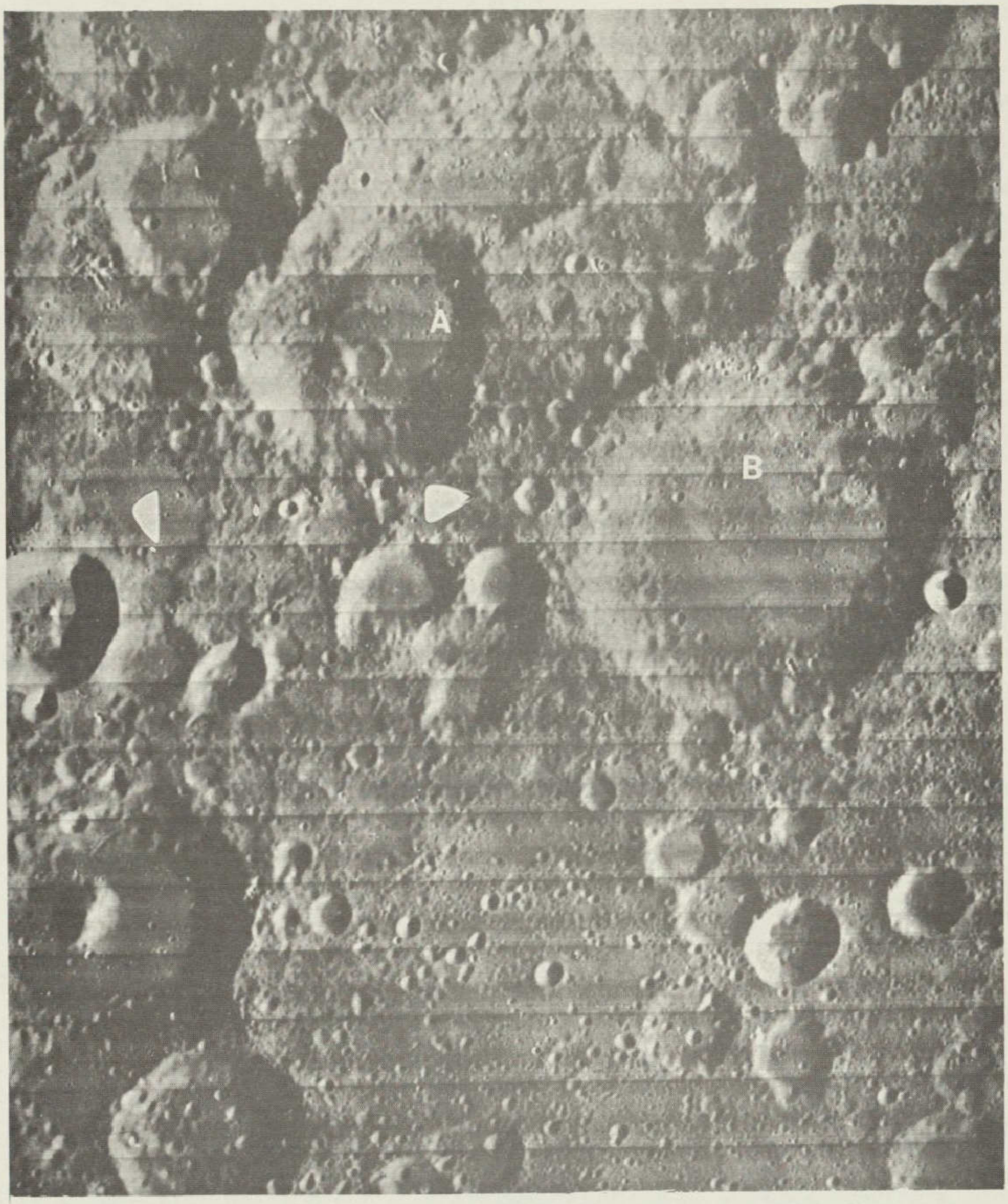


Figure 3.--Area around the craters Cuvier and Heraclitus. The smooth plains unit appears to overlap the cratered plains. Most apparent overlap occurs in crater Cuvier, A; less apparent in crater Heraclitus, B.

Some c_3 craters (for example, Longomontanus P, southeast of Longomontanus outside the quadrangle) appear to have formed on the plains unit. In addition, these craters have not been filled to as great a depth as other c_3 craters of similar size, suggesting that they formed during the time period that the plains unit was being deposited.

Crater materials.--One c_4 crater, Rutherfurd, deserves special comment (fig. 4). The freshness of Rutherfurd and its sharp satellitic craters suggest a Copernican age. Rutherfurd, however, is older than the Tycho rays, and ray material from Rutherfurd, if present, is masked by the Tycho ray system.

Ejecta from Rutherfurd occurs on the floor and southern rim of Clavius. On the floor of Rutherfurd and embaying its ejecta on the floor of Clavius is a dark, virtually uncratered, very smooth material (unit pvs) (fig. 4A). This material cuts rays of the Copernican crater Tycho and must therefore also be Copernican.

Some craters in the southern and east-central parts of the quadrangle appear to have formed by secondary impact and are generally radial to the crater Moretus, to which they can be traced on the south (fig. 4C). Moretus, approximately 30 km south of Clavius, is very similar to Tycho in size, relative freshness, and general character, suggesting that it too may be Copernican. It is surrounded by a dune-like terrain and fresh satellitic craters but lacks a discernible ray pattern. (The absence of ray material may be due to mantling by the smooth plains unit (ps), suggesting that the last episodes of ps deposition may be as young as Late Eratosthenian or Copernican.)

Between Lilius and Jacobi, probable c_3 craters similar to one another in size and morphology are anomalously abundant (fig. 5). Chains and clusters of these craters have a general linear north-northeast trend that does not coincide with the "lunar grid". Some of them appear to be clusters of two or three overlapping craters. Because they all appear to be the same age, are about the same size, and are linearly oriented, they may represent impacts of a meteorite swarm or volcanic craters. The writer prefers the meteorite swarm hypothesis.

Albedo.--Ray material from Tycho, which covers almost all the quadrangle, was not mapped; figure 6 is a photograph of the Clavius region showing the Tycho rays. This high-albedo material masks the albedo of the materials underlying it; thus, albedo values were not assigned.

Lineaments.--Lineaments, which may represent fractures or tectonic joints, are present throughout the quadrangle. Over 640 lineaments have been plotted. Many additional more subtle lineaments are visible in Lunar Orbiter photographs. Figure 7 shows the percent frequency of lineaments plotted against their azimuths in 10° increments. The eastern sector contains 53 percent of the lineaments, the western sector 47 percent. The greatest concentration, totaling approximately 27 percent, is between N. 20° E. and N. 40° E., and lesser concentrations occur at N. 40° E.-N. 50° E.

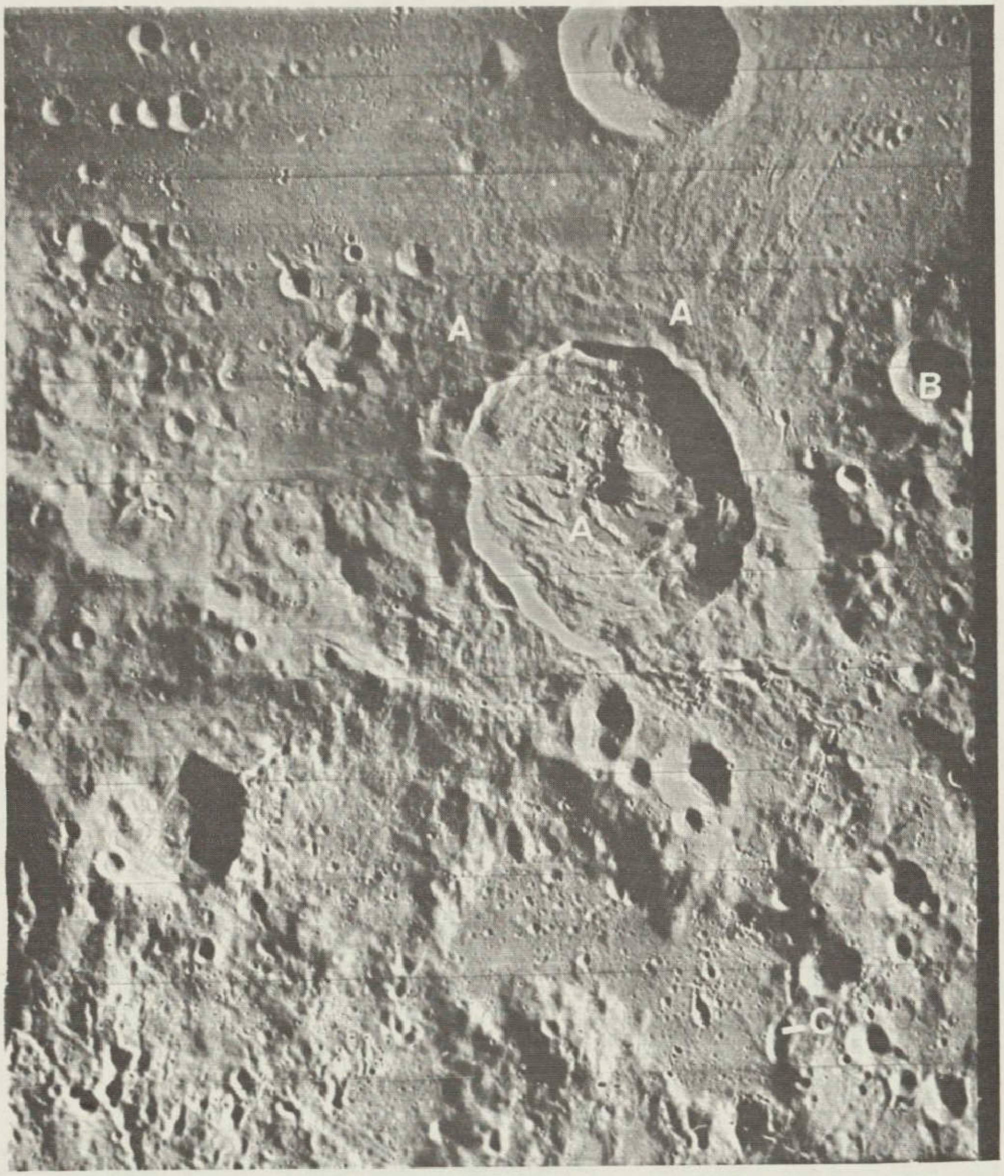


Figure 4.--Area around the crater Rutherfurd. Very smooth patches of plains unit (pvs) cut ejecta of Rutherfurd and form on the floor of Rutherfurd A. Mound of ps may be seen in crater east of Rutherfurd, B. Certain craters, C, are interpreted to be satellitic to Moretus.

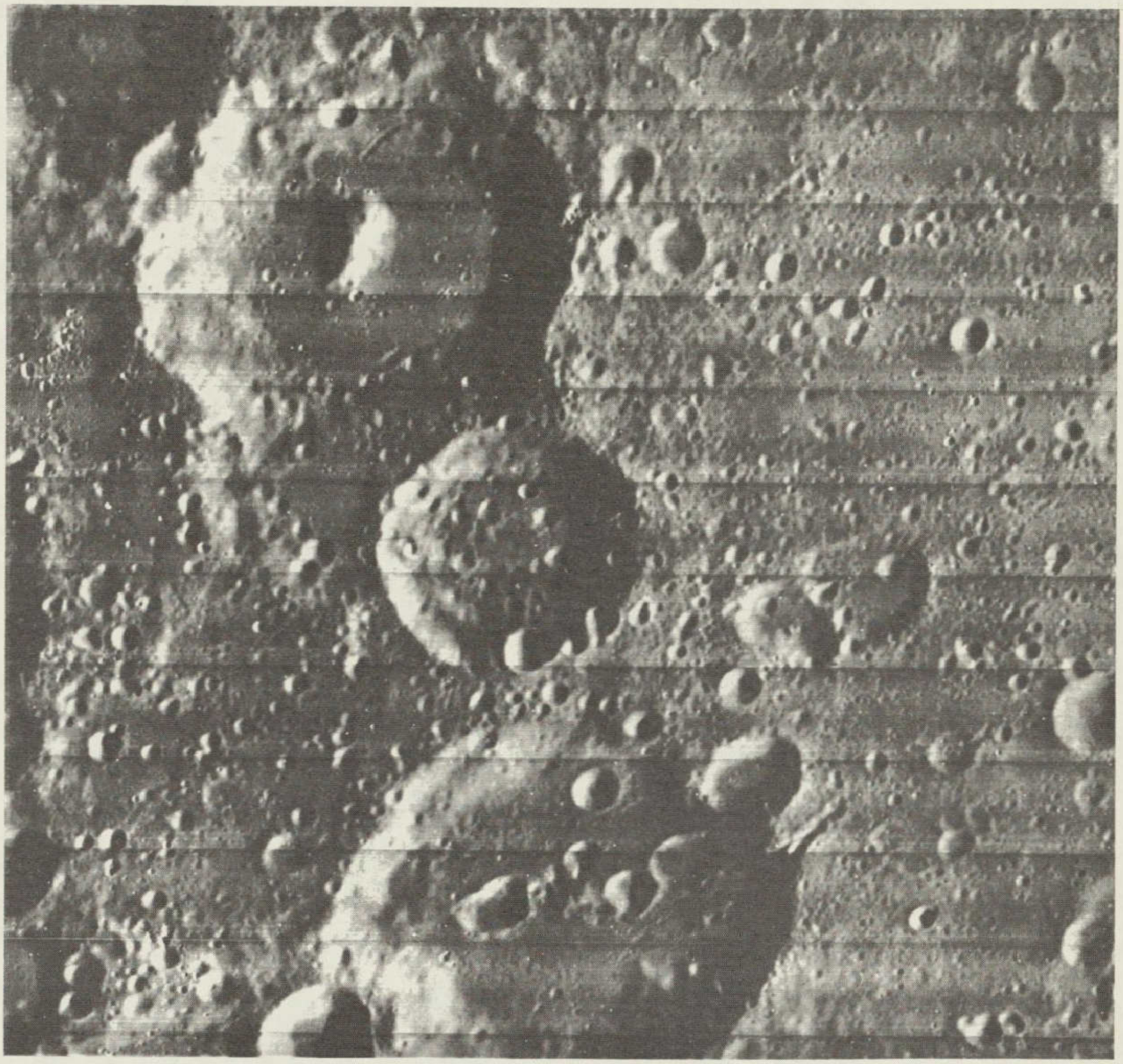


Figure 5.--Craters Lilius (top) and Jacobi (bottom). An anomalously high concentration of c_3 craters is visible in the picture. These craters all appear to be similar in age, size, and trend (north-northeast).

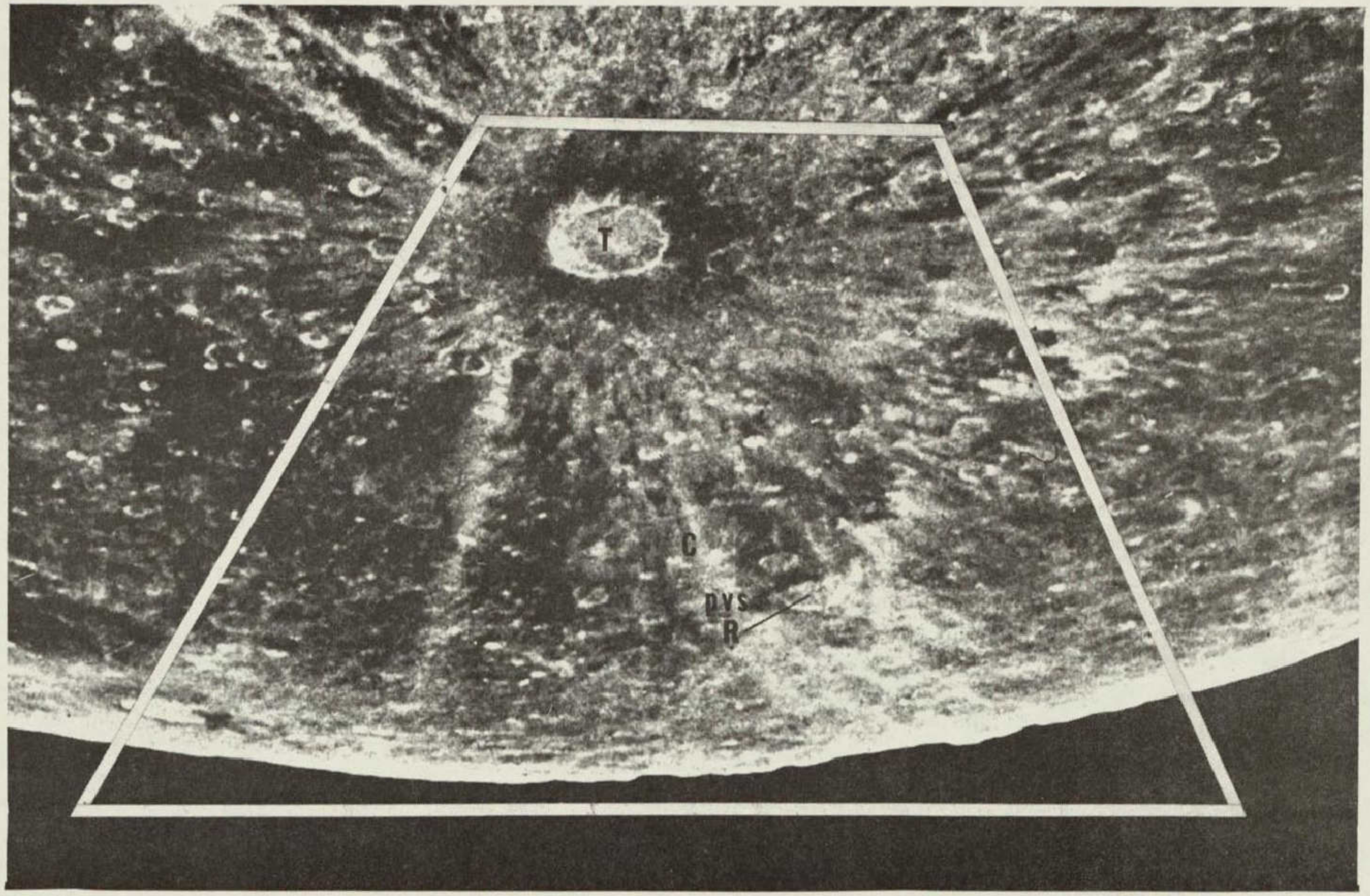


Figure 6.--Full-moon photograph of the Clavius quadrangle and vicinity. C = Clavius, R = Rutherfurd, pvs = plains unit, very smooth, T = Tycho.

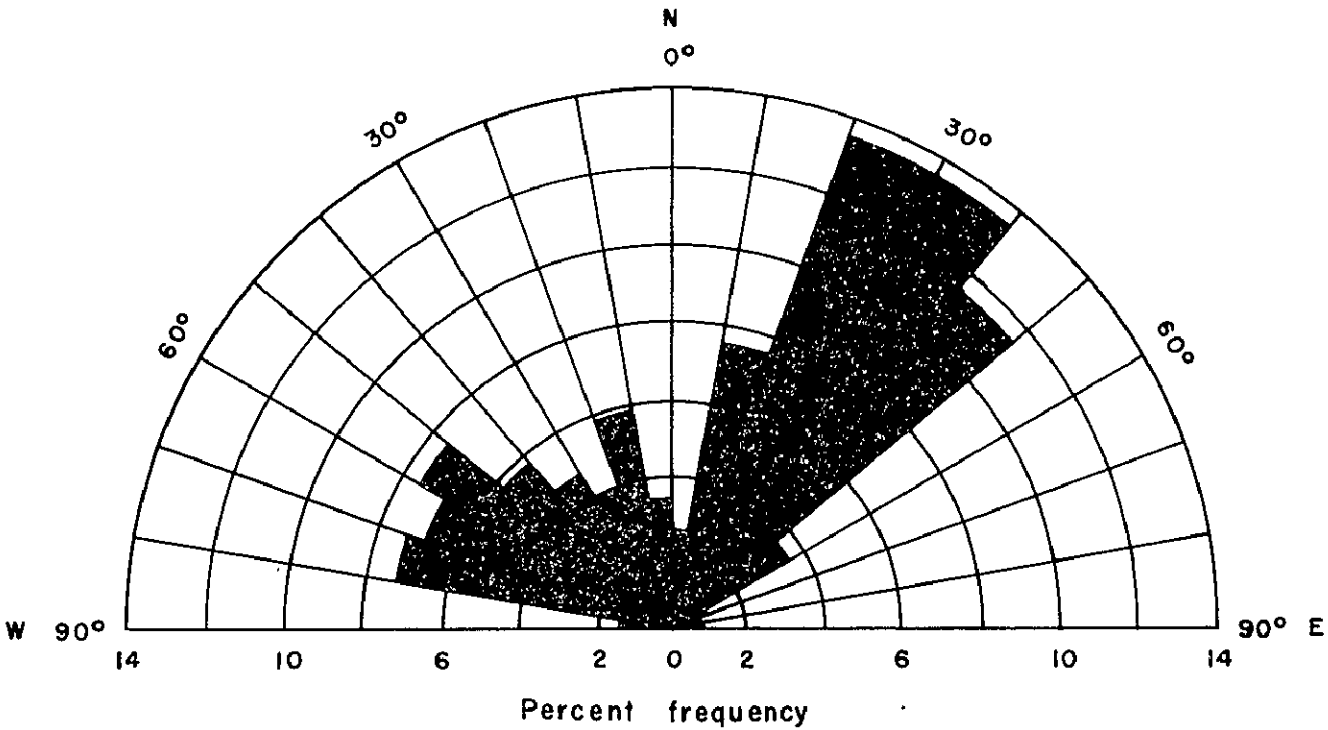


Figure 7.--Orientations of strike directions of lineaments plotted against their frequency. Total lineaments counted was 643.

(11.5 percent) and N. 10° E.-N. 20° E. (7.5 percent). Lineaments trending between north and west are more evenly distributed than those trending between north and east, and they do not display any major concentrations. Two minor concentrations occur at N. 10° W.-N. 20° W. (about 6 percent) and between N. 50° W.-N. 80° W. (totaling almost 22 percent).

The major general concentrations of about N. 30° E. and N. 60° E. may represent a set of tectonic shear joints, the bisector of which strikes N. 15° W. Because of age relations of lineaments or lineament sets are not generally consistent, the lineaments may have formed intermittently without a consistent temporal order.

Subdued lineaments occur on the hummocky facies of the plains units but have not been recognized on the smooth facies, suggesting that lineaments show through the thin mantle of material of the hummocky unit but not through the thick smooth plains. Alternatively, lineaments may have not developed or been reactivated since the plains units were deposited.

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